Open Analysis Addressing Slavery in Supply Chains

OAASIS

THE UNIVERSITY OF SYDNEY

Structural Path Analysis for assessing modern slavery risk in supply chains

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Summary

This document provides a pedagogical introduction to Structural Path Analysis, and its application to quantifying the risk of modern slavery in supply chains. It is accompanied by a lecture in which the fundamental concepts are explained in more detail and illustrated with practical examples. The lecture is provided in the form of a video recording as well as the corresponding lecture slides, both available for download. Note that basic knowledge of Extended Input Output Analysis (EIOA) is assumed throughout.

1. Introduction

Structural Path Analysis (SPA) is the process of unravelling the intricate economic interactions among the sectors in an economic system into individual supply chains or structural paths (*paths*, for short). Each abstract path thus represents a *causal* economic transaction, with a consumer at one end, followed by – in principle – an infinite, linear chain of *upstream* suppliers.

SPA corresponds to a deeper level of the decomposition that follows from the technique known as Production Layer Decomposition (PLD). PLD breaks down the economic transactions between sectors into an aggregate of transactions at different levels, or *layers* of production: The consumer sits at layer 1 (by definition); *its* direct suppliers sit at layer 2; *their* suppliers, at level 3; and so on up to, again in principle, an infinite number of layers. SPA then splits the aggregate transactions at each layer into individual transactions, i.e., paths.

SPA serves a double purpose: 1) It allows to identify the sector or sectors that carry the highest impact, i.e., *footprint* – measured in terms of environmental or social indicators – in an economic system; 2) It informs how far upstream the highest impacts are occurring.

PLD, and by extension SPA, follow from the economic analysis method known as Extended Input Output Analysis (EIOA), thus are subject to its limitations (for a discussion; see (Lenzen 2007; Kanemoto and Murray 2010; Wiedmann et al. 2009)).

2. Fundamentals

SPA derives entirely from the following:[1]

1) The mathematical expression for the footprint Q (also known as *total impacts*),

$$Q = m\, y,$$

where y is the final demand, and the *multipliers* are given by,

$$m = q\, L,$$

Here, q are the direct impacts and L is the Leontief matrix.

2) The fact that L can be expressed as a power series in the *direct requirements* matrix A,

$$L = I + A + A^2 + A^3 + \cdots,$$

Combining the last two equations the footprint (or total impacts) is given by,

$$my = q\,(I + A + A^2 + A^3 + \cdots)\, y\,.$$

This last equation is discussed in detail the lecture. In there, it is explained step-by-step how it is applied to arrive at the definition of a supply chain (or structural path).

In brief, a supply chain is represented by a product of the form,

$$q_n A_{nm} \ldots A_{ij} y_j,$$

where the number of A-factors determines the *order* of the supply chain. A supply chain can have any order between 0 and ∞. For example, the expression $q_n y_n$ represents a supply chain of order 0, whereas $q_n A_{nm} A_{mj} y_j$ represents a supply chain of order 2. A supply chain of order k is assigned to a layer $k+1$. The *value* of a supply chain is simply the number resulting from carrying out the multiplication of all its factors, and it represents the impact – as measure by the indicator q – of the economic transaction carried out between sector n and sector j (in the above example) through the entire economy.

3. Examples

Structural path analysis has been used for assessing the impacts of businesses on Norfolk Island (Lenzen 2008), for identification of carbon hotspots and quantification of greenhouse gas intensities in biodiesel supply chains (Acquaye et al. 2011), for analysing ecosystem networks (Lenzen 2007), for analysing the supply chain impacts of health care sectors at a global scale (Lenzen et al. 2020) and for specific countries, such as China (Wu 2019), for analysing economic complexities (Sonis and Hewings 1998), and many more. In this project, structural path analysis has been used as a technique for assessing modern slavery risks in supply chains, specifically by linking a modern slavery satellite to an input-output database for identifying slavery-related hotspots in supply chains.

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[1] For simplicity, we assume here that both y and q are vectors of size N, where N is the number of sectors in the economy. L is correspondingly a square matrix of size $N \times N$.

4. The OAASIS Tool

As part of the *OAASIS* project we have developed an online tool to conduct Structural Path Analysis (SPA), called **spaJS** (a.k.a. the OAASIS tool). The tool has been written from scratch entirely in JavaScript; it runs in the local browser, and is fully dynamic, i.e. data-driven and interactive. One of the main features of spaJS is that the result from each run can be both saved to disk and *visualised* directly in the browser session (see Figure 1). An additional feature (available soon) is the geographic visualisation of the links between the countries within the economic system represented by the input data. For more details on its usage we refer the reader to spaJS's User Guide, linked to the tool's interface.

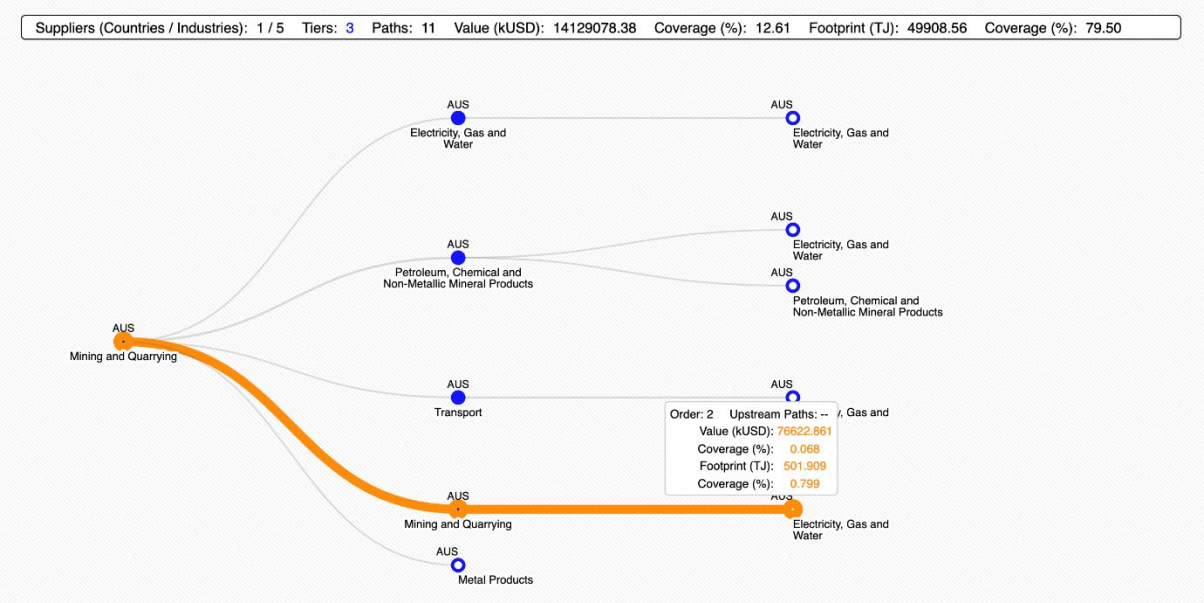

Figure 1. Example of a supply chain visualisation with spaJS.

spaJS is made freely available to the community exclusively for non-commercial purposes and can be found at: http://www.physics.usyd.edu.au/spajs/ .

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